Physics of the Solid State, Vol. 43, No. 2, 2001, pp. 214–217. Translated from Fizika Tverdogo Tela, Vol. 43, No. 2, 2001, pp. 207–209.

METALS AND SUPERCONDUCTORS

Giant Quantum Oscillations of the Magnetothermoelectric Coefficient in Semimetallic Sb–Bi and Sb–As Alloys

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Received February 28, 2000; in final form, June 27, 2000

Abstract—Quantum oscillations of the magnetothermoelectric coefficient $\alpha_{ii}(B)$ are investigated in semimetallic Sb–Bi and Sb–As alloys in stationary magnetic fields up to 15 T and at temperatures from 1.9 to 30 K. Quantum oscillations of $\alpha_{ii}(B)$ of a giant amplitude are observed when the longitudinal or transverse magnetic field is oriented along a binary C_2 axis or a bisectory C_1 axis and also when rotating the transverse magnetic field in angle ranges up to [+55°, –55°] around them. *© 2001 MAIK "Nauka/Interperiodica".*

Quantum oscillations of the resistance $\rho_{ii}(B)$ and the thermoelectric coefficient $\alpha_{ii}(B)$ in a normal metal (semimetal) are known to be affected in a different way by changes in the scattering processes and by the dependence of the relaxation time of charge carriers on energy $\tau(\varepsilon)$ in a magnetic field. For example, the $\tau(\varepsilon)$ dependence in a magnetic field is not of great importance [1] for the Shubnikov–de Haas effect as the oscillation amplitudes are not very large (~10% of the monotonic part of the resistance) and, in principle, can reach the value of the monotonic part only in sufficiently high fields. The opposite situation occurs for the diffusive part of the magnetothermoelectric coefficient at low temperatures (the net thermoelectric coefficient consists of two components: the diffusive component and that one associated with the phonon-drag effect); its monotonic part is proportional to $\sim(kT/\varepsilon_F)$ and is very small, and the dependence of the relaxation time of charge carriers on energy in a magnetic field can result in [1] anomalously large oscillation amplitudes of $\alpha_{ii}(B)$.

In the present work, the quantum oscillations of $\rho_{ii}(B)$ and $\alpha_{ii}(B)$ are investigated in high-quality samples of Sb (the Fermi surface of Sb consists of three electron pockets centered at the L points and six hole pockets localized at the H points of the Brillouin zone [2]) and the alloys As_xSb_{1-x} ($x \leq 0.5$) and $Bi_{1-x}Sb_x$ ($x \geq 0.25$) in stationary magnetic fields up to 15 T and at temperatures from 1.9 to 30 K. The measurements are performed in the International Laboratory of High Magnetic Fields and Low Temperatures (Wroclaw, Poland). The samples for the measurements are produced by a zone-melting method, and their composition was controlled by laser spectroscopy techniques and by x-ray microprobe analyzers. The main results obtained are presented below.

In Sb, the quantum oscillation amplitudes of $\alpha_{ii}(B)$ are not large and amount to as much as several percent of the monotonic component. In contrast, in the alloys As_xSb_{1-x} ($x \leq 0.3$) and $Bi_{1-x}Sb_x$ ($x \geq 0.5$), whose Fermi surface is similar to that of Sb [3, 4], the quantum oscillations of the $\alpha_{ii}(B)$ exhibited giant amplitudes (in some samples, $\alpha_{ii}(B)_{\text{osc}}/\alpha_{ii}(B)_{\text{mon}} \sim 16$) at the orientation of the longitudinal or the transverse magnetic field along a binary C_2 axis or a bisectory C_1 axis and at the rotation of the transverse field in an angle range $\Delta\theta$ around them (Figs. 1, 2). When the As concentration in the As–Sb alloys is increased, $\Delta\theta$ decreases from about [+35°, –35°] at $x = 0.05$ to [+20°, –20°] at $x = 0.3$, and when the Bi concentration in the Bi–Sb alloys is increased, $\Delta\theta$ increases from [+35°, –35°] at $x = 0.95$ to [+55°, –55°] at $x = 0.5$. It should be noted that the giant quantum oscillations (GQO) of the magnetothermoelectric coefficient exhibited the same period as the oscillations of $\rho_{ii}(B)$. The Fourier analysis of these oscillations clearly separated out the frequencies inherent in the energy spectrum of Sb [2] and its alloys with As and Bi. Their identification and their dependence on the alloy composition are presented in [3, 4]; the oscillating part of the magnetoresistance was no more than 10% of the monotonic part of the $\rho_{ii}(B)$.

The quantum oscillations of the magnetothermoelectric coefficient in the case when the magnetic field is oriented outside the $\Delta\theta$ range (with an accuracy of 3–5 %) are described by the existing theories [5, 6]

$$\frac{\alpha_{ii}(B)_{\text{osc}}}{\alpha_{ii}(B)_{\text{mon}}} \approx \frac{2\pi\varepsilon_F}{\hbar\omega}\frac{\rho_{ii}(B)_{\text{osc}}}{\rho_{ii}(B)_{\text{mon}}},$$

and their amplitude is not anomalously large.

The temperature dependences of the GQO amplitude of the magnetothermoelectric coefficient $\tilde{\alpha}_{ii}(T)$ in the Sb-based alloys with Bi and As (Fig. 3), as well as the temperature dependences of the longitudinal magnetoresistance in Bi, exhibited a nonmonotonic character with a maximum at $T = T_m$ ($T_m \leq 11$ K), whose posi-

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